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RESEARCH MEMORANDUM

PRELIMINARY INVESTIGATION OF LAND-WATER OPERATION WITH A 1/10-SCALE MODEL OF A JET AIRPLANE EQUIPPED WITH HYDRO-SKIS

By William C. Thompson

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NATIONAL ADVISORY COMMITTEE
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RESEARCH MEMORANDUM

PRELIMINARY INVESTIGATION OF LAND-WATER OPERATION WITH A 1/10-SCALE MODEL OF A JET AIRPLANE EQUIPPED WITH HYDRO-SKIS

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SUMMARY

An investigation of a 1/10-scale dynamically similar model of a jet airplane equipped with hydro-skis was made to study the transition between ramp and water during take-off and landing operations. The hydro-skis were installed so that they utilized the existing landing-gear shock absorbers. One configuration employed a twin-ski arrangement and the other a tri-ski arrangement. The investigation included observations (both visual and photographic) of general behavior, stability, and spray characteristics. Longitudinal and normal accelerations were measured with a two-component accelerometer. A brief investigation was made to observe the behavior and measure the resistance during take-off runs.

From the results of the investigations with the twin-ski configuration it was concluded that satisfactory take-off transitions (from ramp to water) could be made when the ramp slope was as steep as 4 to 1. Considerable spray was thrown out to the sides but none entered the nose air inlet. Satisfactory take-off transitions were also made from ledges as high as 4 feet. Generally, the landing transition (from water to ramp) was a very smooth operation since there was little trim change involved with slopes as steep as 6 to 1. With a 4-to-1 slope there was a considerable bounce when the nose wheel contacted the ramp. The take-off tests indicated good stability and satisfactory resistance for take-off with a water-entry speed of approximately 50 knots.

The tri-ski configuration could be operated on ramp slopes as steep as 6 to 1. The take-off and landing stability, however, were unsatisfactory with the main skis in any position suitable for attachment to the main landing-gear struts.

INTRODUCTION

Full-scale operations have been conducted with light-weight propeller-driven airplanes equipped with hydro-skis, where the major portion of the take-off and landing run was made on the water with the airplane starting from and returning to a solid base. (See ref. 1.) Such an operation may present some difficulty when a larger airplane, such as a jet-powered fighter, is considered. Consequently, an investigation was conducted at the Langley Aeronautical Laboratory with a dynamically similar model of a jet airplane to investigate the range of conditions under which hydro-ski-equipped airplanes of this type could freely enter and leave the water, starting from and returning to solid bases of various types such as ramps, beaches, rafts, or special aircraft carriers.

The model was chosen for this investigation because of its availability and the fact that a twin hydro-ski designed for land-water transition take-off and landing was available. It was anticipated that the information obtained would be applicable to current high-performance airplanes. The investigation included transitions from ramp to water and water to ramp with the ramp at various slopes. Transition from a ledge to water was also investigated. Brief take-off and landing tests were made.

In addition to the twin-ski arrangement, a simple tri-ski design was tested as a possible alternate configuration.

APPARATUS AND PROCEDURE

Description of Model

Figure 1 is a three-view drawing of the airplane illustrating the final arrangements of the two hydro-ski configurations that were tested. Figures 2 and 3 show details of the hydro-skis. In the case of the twin skis the manufacturer's proposal included fairings on the fuselage bottom which permitted the skis to be retracted in a relatively clean condition. However, for simplicity in the model tests the fairings were omitted. The tri-skis were of a simple flat-bottom type. The three skis had approximately the same total area as the twin skis. Both configurations are intended to be used in conjunction with the landing gear already on the airplane and employ the existing shock absorbers as load-alleviating devices for the hydro-skis.

Pertinent dimensions of the model and the full-scale airplane are given in table I. The 1/10-scale dynamic model used for the investigation is shown in figure 4. The model was constructed principally of plastic and fiber glass. Internal ballast was used to obtain scale weight and weight distribution. The flaps and elevators were installed so that they could be fixed in various positions. The approximate shock-absorbing characteristics of the main landing gear were simulated with oleo shock struts and flexible tires made from a rubberlike plastic. The nose-gear strut was made rigid. The main-gear shock strut of the airplane had a total stroke of 9 inches and a static deflection of $7\frac{3}{16}$ inches. The compression ratio from extended position to static position was 3.65 to 1 and from static to fully compressed was 3 to 1. These values were simulated on the model shock strut. The wheels extended slightly below the skis for all transition tests and the skis were extended slightly below the wheels for the landing and take-off tests.

Test Conditions

The model was investigated at the following test conditions (all values are full scale): A gross weight of 20,000 and 17,000 pounds was simulated for all take-offs and landings, respectively. The model in the 20,000-pound condition was ballasted to approximately the following values of moments of inertia:

Roll, slug-ft^2	10,700
Pitch, slug-ft^2	20,400
Yaw, slug-ft^2	28,300

Flap deflections of 20° and 38° were used for take-off tests and all other tests were made with a 38° flap deflection. The center of gravity was located at 22.1 percent of the mean aerodynamic chord ($0.221\bar{c}$) and 0.94 foot (full scale) below the fuselage reference line. The twin hydro-ski configuration was tested only as shown in figure 1(a). In an effort to find a usable tri-ski configuration, tests were made with the main skis at various locations between that shown in figure 1(b) and a point 30 inches aft. Various angles of incidence of the main skis (0° to 9°) and nose ski (0° to 8°) were used. Tests were also made with one additional nose ski that had the same beam and approximately one-half the total area of the nose ski shown in figure 3.

Test Methods and Equipment

The investigations were made in Langley tank no. 2 with the monorail equipment and the main towing carriage. Data pertaining to general behavior were obtained from motion pictures and from visual observation. Accelerations were recorded by a two-component time-history accelerometer installed in the pilot's compartment. The accelerometer components had natural frequencies of 73 cycles per second and were damped to about 65 percent of critical damping. The reading accuracy of the instrument was $\pm\frac{1}{4}g$.

Entering water.- The transitions from ramp to water were made with the ramp setup shown in figure 5. The model was towed down the ramp by a cable arrangement attached to the monorail towing carriage so that the model was accelerated to approximately 50 knots (full scale) just before the skis contacted the water. Prior to water contact the towing cable was released and the model made the transition as a free body. The ramp was set at various slopes by raising or lowering the upper end. Transitions from a ledge to water were made in a similar manner but with the surface of the ramp parallel to the water surface and at various heights above the water.

Leaving water.- The transitions from water to ramp were made with the ramp shown in figure 5; however, the ramp was relocated so that it was about 30 feet from the end of the monorail and was turned (180°) so that the lower end faced the monorail. The model was free launched onto the water, from the gear shown in figure 6, with sufficient speed so that contact with the ramp was made just above minimum planing speed, approximately 30 knots (full scale). The model then taxied up the ramp.

Landing.- Landings were made by catapulting the model into the air to permit a free glide onto the water. These launchings were also made from the gear shown in figure 6. The model left the launching carriage at 110 knots (full scale) and the desired landing trim (9°) with the control surfaces set so that the angle did not change appreciably in flight. Trim is defined as the angle between the smooth water surface and the fuselage reference line.

Taking off.- The model setup for making take-off tests with the main carriage is shown in figure 7. The model was free to trim and rise but was restrained in roll and yaw. Resistance and trim were determined with the model towed from the normal center of gravity ($0.221\bar{c}$). The resistance was measured with an electrical strain gage while trim was read visually from a pointer and scale.

The model was not powered for the take-off tests but the thrust moment corresponding to 9,000 pounds of thrust (full scale) was simulated on the model with a balance weight. Corrections to the measured resistance for the lift due to thrust were also made. The corrections were based on the assumption that the ratio of the load on the water to the resistance remained constant with small changes in the load on the water as follows:

$$\Delta = \Delta_o - \text{Aerodynamic lift}$$

$$\Delta_c = \Delta - \text{Lift component of thrust}$$

$$R_c = \frac{R}{\Delta} \Delta_c$$

where

R	water resistance, lb
R_c	corrected value of R, lb
Δ	load on water, lb
Δ_c	corrected value of Δ, lb
Δ_o	initial load on water (gross load), lb

RESULTS AND DISCUSSION

The accelerations and behavior for the twin-ski and the tri-ski configurations are presented in table II. Values given are the maximum for the three to five runs made for each condition. The blank spaces in table II indicate that the accelerations were not measured for these conditions. The maximum longitudinal decelerations were from $1\frac{1}{2}g$ to $3g$ when the model entered the water from the various slope ramps with the twin-ski or the tri-ski configuration; the maximum normal accelerations recorded at the same time were from $3\frac{1}{2}g$ to $5g$. Entering the water from the various ledge heights resulted in maximum normal accelerations of $4g$ to $7g$ for the twin-ski configuration. Leaving the water on the various ramp slopes resulted in maximum longitudinal decelerations and maximum normal accelerations approximately 30 percent less than those encountered on water entry.

Figure 8 shows sequence photographs of typical behavior of the model with the twin-ski configuration entering and leaving the water from a ramp. Plots of take-off resistance and trim are shown in figure 9, and figure 10 shows sequence photographs of a take-off run with the twin-ski configuration.

Twin-Ski Configuration

Entering water.- The ramp-to-water transitions with the twin-ski configuration resulted in a very smooth operation for a ramp slope of 10 to 1. There was a gentle trim change as the model entered the water. The initial water entry produced a considerable amount of spray but most of the spray was thrown out to the sides and none entered the nose air inlet. There was, however, considerable spray impinging on the flaps.

When the model entered the water from the ramp with a slope of 6 to 1, there was a moderately fast trim up and a small bounce. Typical behavior is shown in the sequence photographs in figure 8(a). Generally the same type of spray pattern was present as with the 10-to-1 ramp slope. In fact, all the water-entry conditions investigated resulted in much the same spray pattern; that is, most of the spray was thrown out to the sides and none entered the nose inlet, but considerable spray impinged on the flaps. When the model entered the water from the ramp with a 4-to-1 slope there was a fast trim up and a skip of about 1/8 the fuselage length.

For water entry from a ledge the behavior was somewhat rougher than that for water entry from a ramp. When launched from the 2-foot-high ledge, the model trimmed up fast after initial water contact and skipped about 1/2 fuselage length. The behavior from a 4-foot-high ledge was similar to that from a 2-foot ledge but the model skipped about 1 fuselage length. Water entry from an 8-foot-high ledge was very rough; the model trimmed up fast and skipped about 2 fuselage lengths.

Very brief water-entry tests made from a 12-to-1 ramp slope into waves approximately 2 feet high and 20 feet long (full scale) resulted in initial water-entry behavior similar to that for calm water. For the ramp slopes of 6 to 1 and 4 to 1 there appeared to be an improvement in behavior. The model did not trim up as fast and less bounce resulted from the initial water contact. When the model entered rough water from a ramp or ledge the skis sliced through the wave crests and thus some of the initial shock of water entry apparently was absorbed by the waves.

Leaving water.- The transition from water to ramp was in general a very smooth operation, especially with a ramp slope of 12 to 1. When the model left the water at about 30 knots (full scale), which is just above the minimum planing speed, the trim of the model was very close to the three-wheel attitude on the ramp and, therefore, practically no trim change occurred. When the model left the water on the 6-to-1 ramp slope a small bounce resulted from contact of the nose wheel with the ramp. Sequence photographs of the model leaving the water are shown in figure 8(b). When the model left the water on the 4-to-1 ramp slope there was a rough bounce when the nose wheel contacted the ramp.

Landing.- The free model landings resulted in very smooth runs. Visual observation indicated very little trim change throughout the run and the deceleration was very gradual.

Taking off.- Plots of total resistance and trims for typical take-off runs with the twin-ski configuration with flap deflections of 20° and 38° are shown in figures 9(a) and 9(b), respectively. The minimum planing speed was approximately the same for the two deflections. Heavy spray impinged on the flaps when they were down 38°, and the model trimmed to 5°. When the flaps were down 20° there was less spray on the flaps, and the model trimmed to 11°. Apparently the heavy spray at the 38° flap condition provided appreciable lift which permitted a low minimum planing speed at the low trim. At speeds below 40 knots the resistance was higher with the 38° than with the 20° flap deflection. At speeds above 40 knots the total resistance was about the same for the two flap conditions, but the greater flap deflection produced more nose-down moment (partly because of spray impinging on the flaps) and consequently a lower trim. Therefore, the 20° deflection is considered to be the more favorable condition.

As shown in figure 9(a), the minimum planing speed was about 28 knots and the maximum resistance occurred at approximately 40 knots. In order to have a moderate amount of excess thrust, a minimum water-entry speed of 50 knots would be desirable. With a water-entry speed of 50 knots the water run part of the take-off would require approximately 21 seconds and about 2,900 feet. It is estimated that the ground run to get to 50 knots would take about 6 seconds and 265 feet. Sequence photographs of a take-off run starting at the minimum planing speed of 28 knots are shown in figure 10.

Tri-Ski Configuration

Brief tests made with the main skis at various positions aft of the location shown in figure 1(b) and with the main skis and the nose ski at various angles of incidence showed instabilities for all phases of operation. The most stable configuration with the existing landing gear and structure of the airplane is that shown in figure 1(b).

Entering water.- Transition from ramp to water with the tri-ski configuration on a 12-to-1 ramp slope resulted in a fairly smooth run but the model changed trim abruptly when the nose ski contacted the water, whereas the trim change with the twin skis was very gradual. Tests with the smaller nose ski resulted in insufficient lift when the model entered the water, and a dive resulted.

When the model entered the water from the 6-to-1 ramp slope all three skis penetrated the water to a depth of about 2/3 the length of the struts. The model trimmed up moderately fast and skipped about 1/8 fuselage length. Tests were not made from a ramp slope of 4 to 1 because it was expected that the model would dive, since the skis had penetrated the water deeply from the 6 to 1 slope.

Leaving water.- The transition from water to ramp with the tri-ski configuration on a ramp slope of 12 to 1 resulted in behavior that was relatively smooth but not as smooth as that for the twin-ski configuration Leaving the water on the 6-to-1 ramp slope resulted in a fairly large bounce when the nose wheel contacted the ramp. Tests were again omitted for the ramp slope of 4 to 1.

Landings.- Landings with the tri-ski configuration resulted in a porpoising motion which began soon after initial water contact and continued during most of the landing run. The porpoising could not be corrected by changes in incidence of the nose ski or the main skis. When the main skis were moved aft as much as 10 inches (full scale) the model dived.

Taking off.- Take-off with the tri-ski configuration could not be completed because of the porpoising instability which was encountered. Figure 9(c) gives plots of total resistance and trim for the portion of the run before instability occurred. Indications were that the main skis would have to be located forward of the main-gear attachment point in order to obtain sufficient stability for take-off.

CONCLUDING REMARKS

From the results of the investigation with the twin-ski configuration it was concluded that satisfactory take-off transition (from ramp to water) could be made when the ramp slope was as steep as 4 to 1. Considerable spray was thrown out to the sides but none entered the nose air inlet. Satisfactory take-off transitions were also made from ledges as high as 4 feet. Generally the landing transition (from water to ramp) was a very smooth operation, since little trim change was involved with slopes as steep as 6 to 1. With a 4-to-1 slope there was a considerable bounce when the nose wheel contacted the ramp. The take-off tests indicated good stability and satisfactory resistance for take-off with a water-entry speed of approximately 50 knots.

The tri-ski configuration could be operated on ramp slopes as steep as 6 to 1. The take-off and landing stability, however, was unsatisfactory with the main skis in any position suitable for attachment to the main landing-gear struts.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., January 6, 1958.

REFERENCE

1. Anon.: Universal Landing Gear for Naval Aircraft. Contract Nonr-1073(00), All American Engineering Co. (Wilmington, Del.), Feb. 1954.

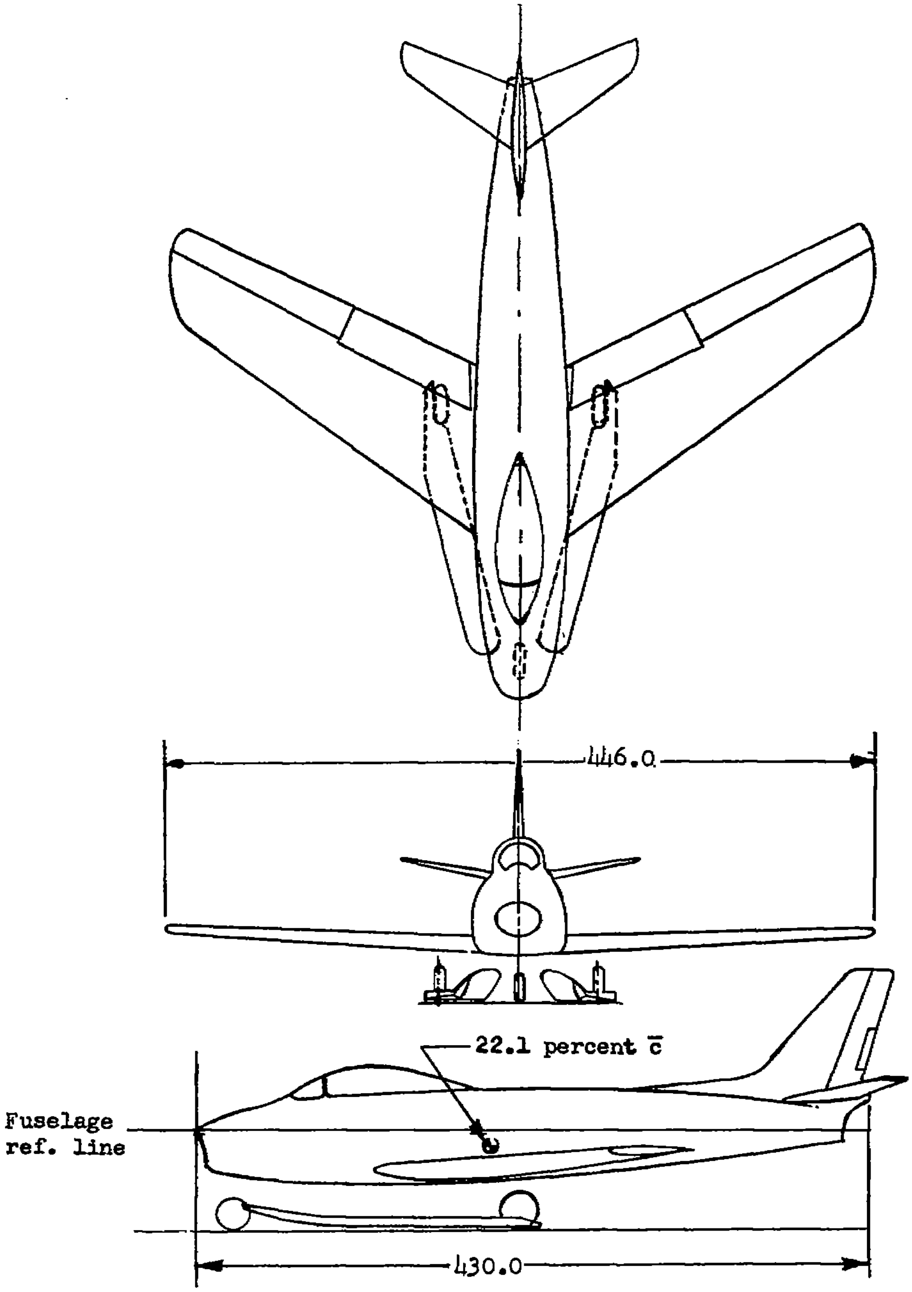
TABLE I.- PERTINENT DIMENSIONS OF THE HYDRO-SKI-EQUIPPED AIRPLANE AND THE 1/10-SCALE DYNAMIC MODEL

	Full scale	Model
Design gross load, lb		
Take-off	20,000	20
Landing	17,000	17
Static thrust, lb	9,000	9
Overall length, ft	38.0	3.80
Overall height, ft	14.5	1.45
Fuselage length, ft	35.8	3.58
Center-of-gravity location		
Percent mean aerodynamic chord	22.1	22.1
Distance below fuselage reference line, ft . . .	0.94	0.094
Wing:		
Area, sq ft	284.0	2.84
Span, ft	37.20	3.72
Mean aerodynamic chord, ft	8.02	0.802
Root chord, ft	10.30	1.030
Tip chord, ft	5.47	0.547
Sweepback, deg	35	35
Flaps		
Take-off position, deg	20	20
Landing position, deg	38	38
Tail:		
Horizontal-tail area, sq ft	17.0	0.170
Horizontal-tail span, ft	12.65	1.265
Vertical-tail area, sq ft	20.2	0.202
Twin hydro-ski:		
Length, ft	16.05	1.605
Beam, ft	1.67	0.167
Length-beam ratio	9.63	9.63
Total area of one ski, sq ft	23.3	0.233
Take-off gross loading, lb/sq ft	430	43
Tri hydro-ski:		
Main ski:		
Length, ft	9.24	0.924
Beam, ft	2.30	0.23
Length-beam ratio	3.75	3.75
Total area of one ski, sq ft	18.4	0.184
Nose ski:		
Length, ft	6.44	0.644
Beam, ft	1.42	0.142
Length-beam ratio	4.53	4.53
Total area of nose ski, sq ft	7.68	0.077
Take-off gross loading:		
One nose ski and two main skis, lb/sq ft . . .	450	45

TABLE II.- ACCELERATIONS AND BEHAVIOR IN CALM WATER OF THE 1/10-SCALE MODEL OF A HYDRO-SKI-EQUIPPED AIRPLANE

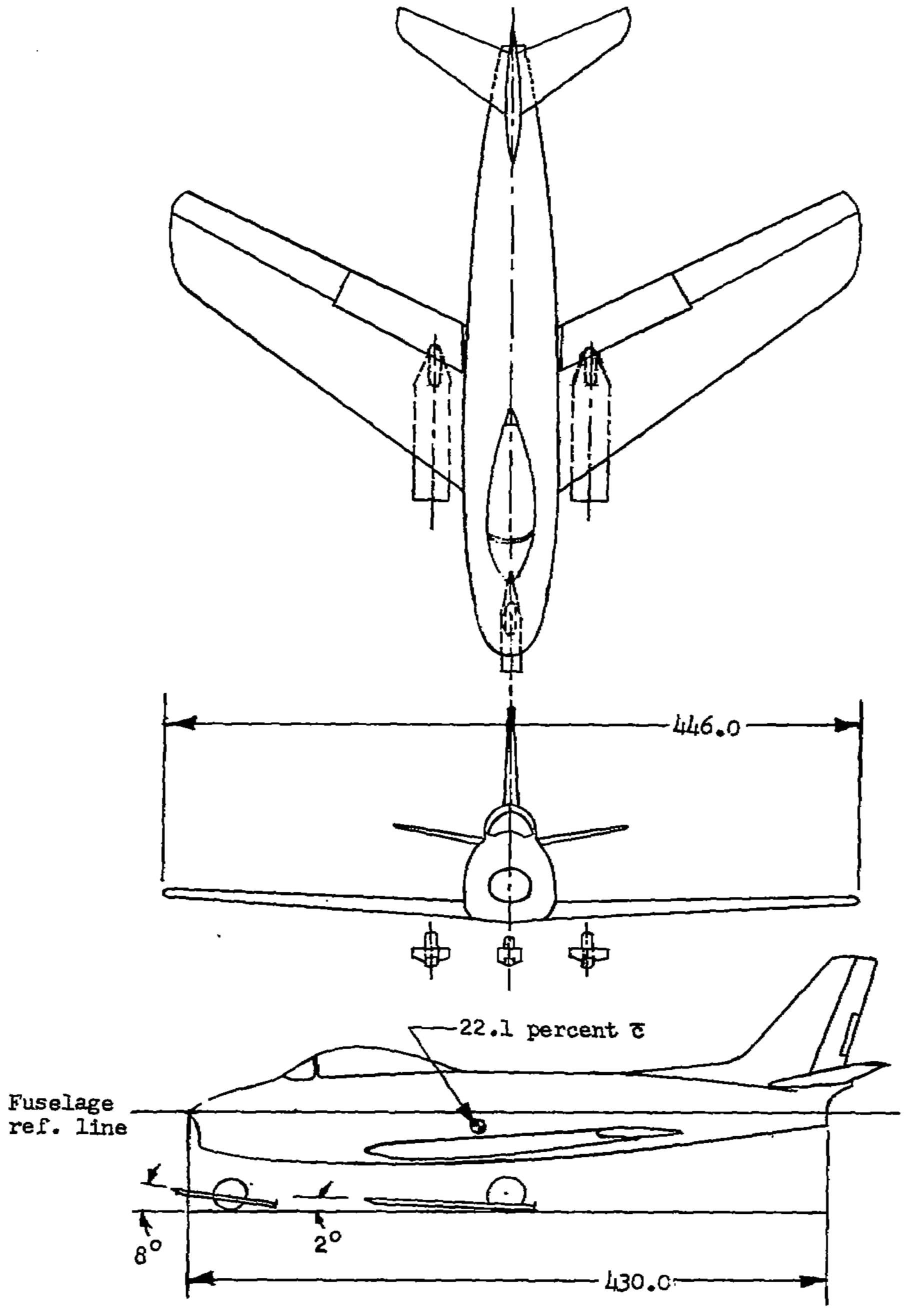
[All values are full scale. Static normal accelerometer reading, 1 g.]

Maneuver	Ramp slope or ledge height	Maximum longitudinal deceleration, g	Maximum normal acceleration, g	Comments
Twin skis				
Entering water (app. 50 knots)	10:1 ramp	$1\frac{1}{2}$	$3\frac{1}{2}$	Smooth with gentle trim change as model entered water
	6:1 ramp	$2\frac{1}{2}$	$4\frac{1}{4}$	Moderately fast trim up; small bounce
	4:1 ramp	3	$4\frac{3}{4}$	Fast trim up; model skipped about 1/8 fuselage length
	2-ft ledge	--	4	Fast trim up; model skipped about 1/2 fuselage length
	4-ft ledge	--	$5\frac{1}{2}$	Fast trim up; model skipped about 1 fuselage length
	8-ft ledge	--	7	Rough with fast trim up; model skipped about 2 fuselage lengths
Leaving water (app. 30 knots)	12:1 ramp	$\frac{3}{4}$	0	Smooth with practically no trim change
	6:1 ramp	$1\frac{1}{2}$	$3\frac{1}{2}$	Small bounce when nose wheel contacted ramp
	4:1 ramp	2	4	Rough bounce when nose wheel contacted ramp
Tri skis				
Entering water (app. 50 knots)	12:1 ramp	$1\frac{1}{2}$	$2\frac{3}{4}$	Fairly smooth; fast trim change when nose ski contacted water
	6:1 ramp	2	4	Skis penetrated water about 2/3 depth of strut; moderately fast trim up; model skipped about 1/8 fuselage length
Leaving water (app. 30 knots)	12:1 ramp	$\frac{1}{2}$	$2\frac{1}{2}$	Smooth with practically no trim change
	6:1 ramp	$1\frac{1}{4}$	--	Fairly large bounce when nose wheel contacted ramp



(a) Twin-ski configuration.

Figure 1.- Three-view drawing of airplane with hydro-skis installed. Dimensions are in inches, full scale.



(b) Tri-ski configuration.

Figure 1.- Concluded.

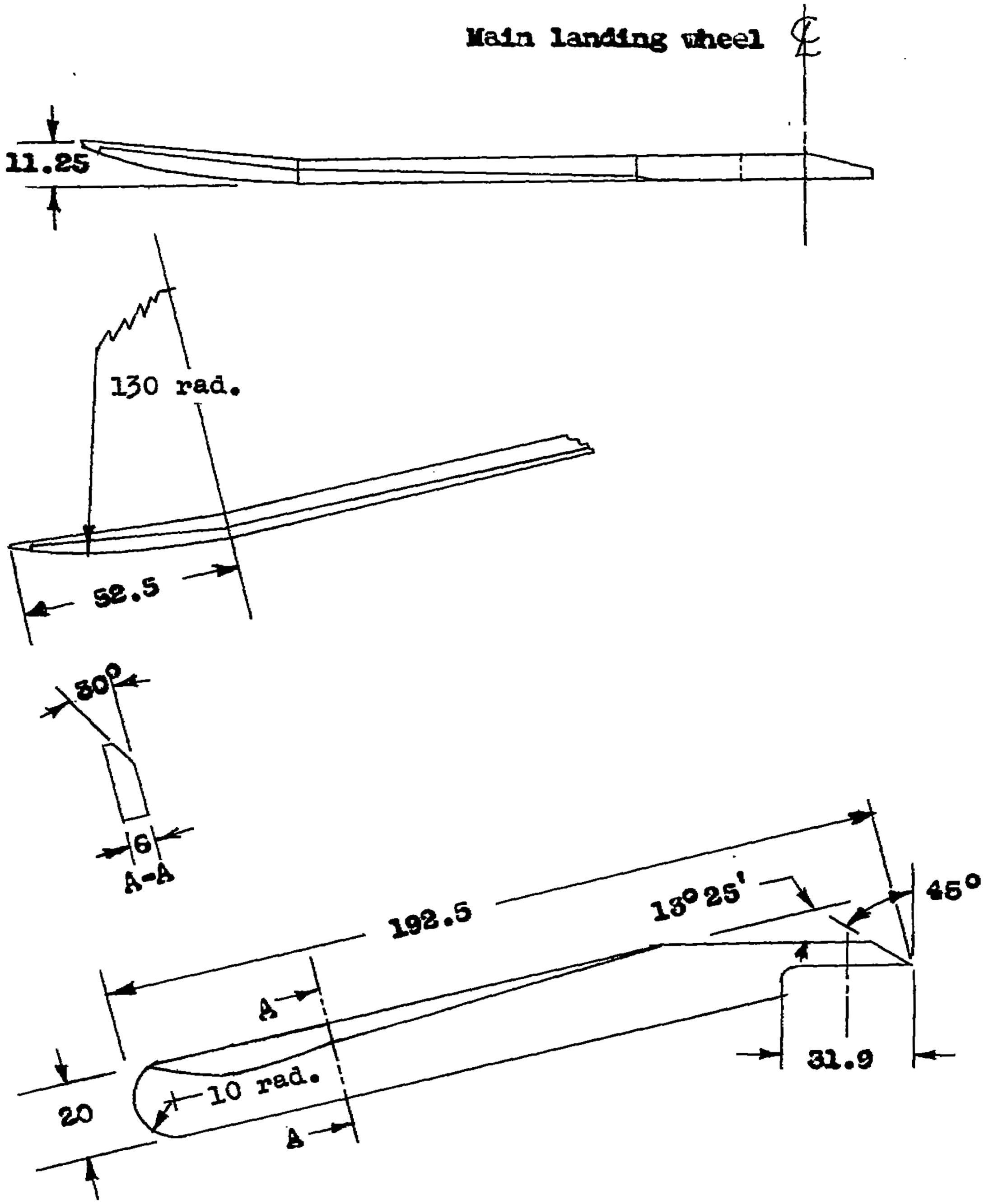


Figure 2.- Hydro-skis used for the twin-ski configuration. Dimensions are in inches, full scale.

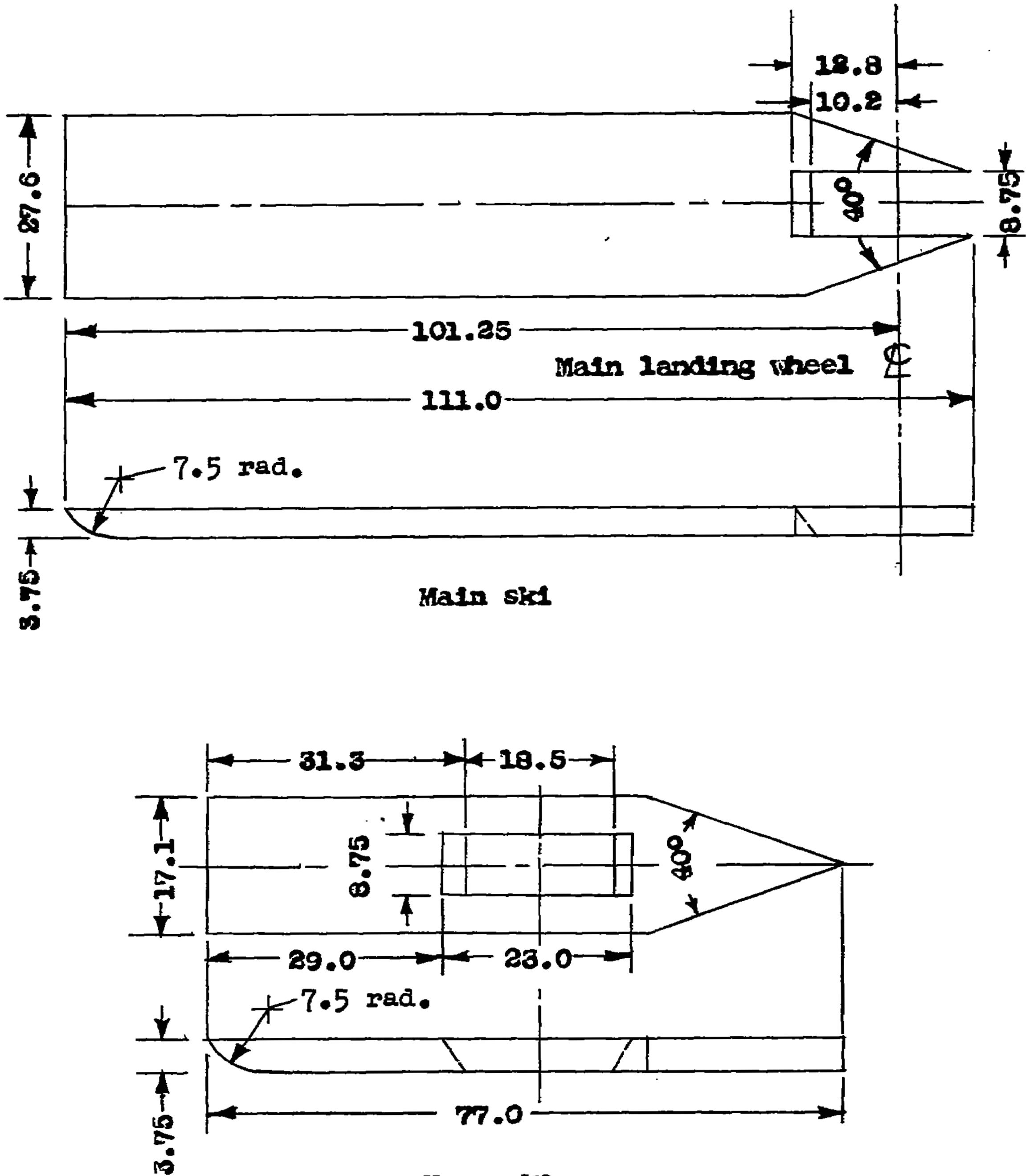


Figure 3.- Hydro-skis used for the tri-ski configuration. Dimensions are in inches, full scale.

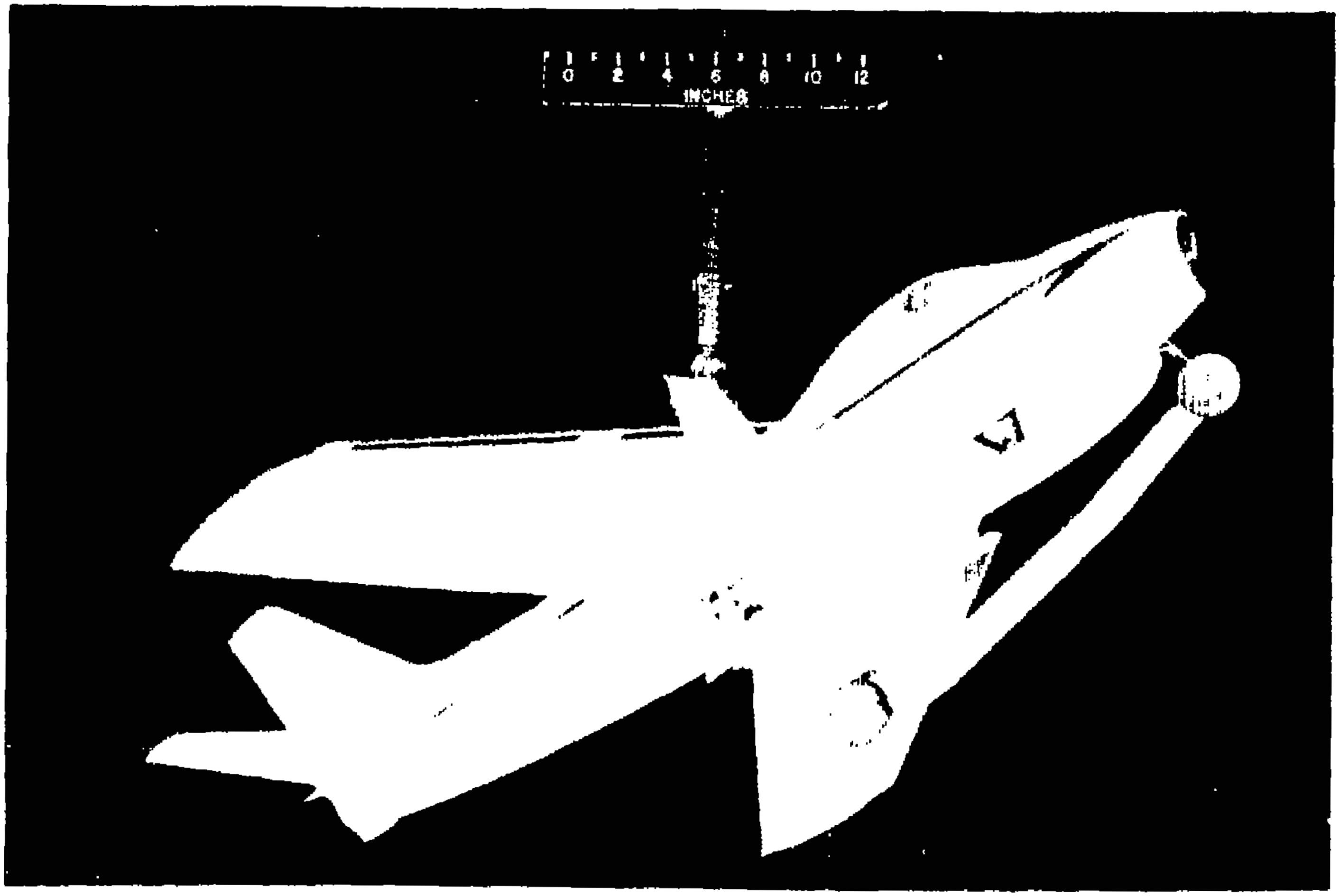


Figure 4.- The model with twin hydro-skis installed. L-87827

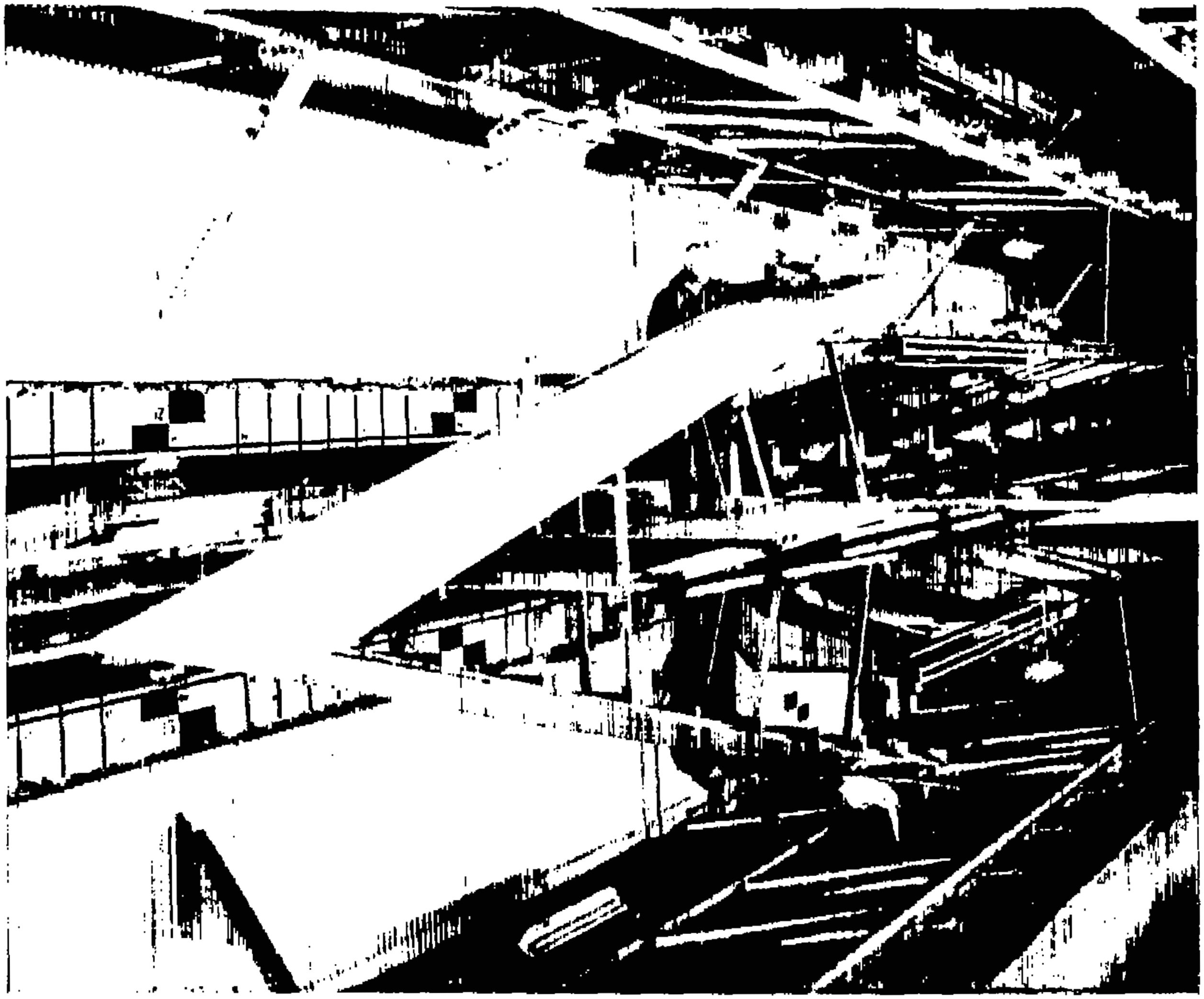


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Figure 5.- Ramp setup for ramp-to-water transition in Langley tank no. 2.

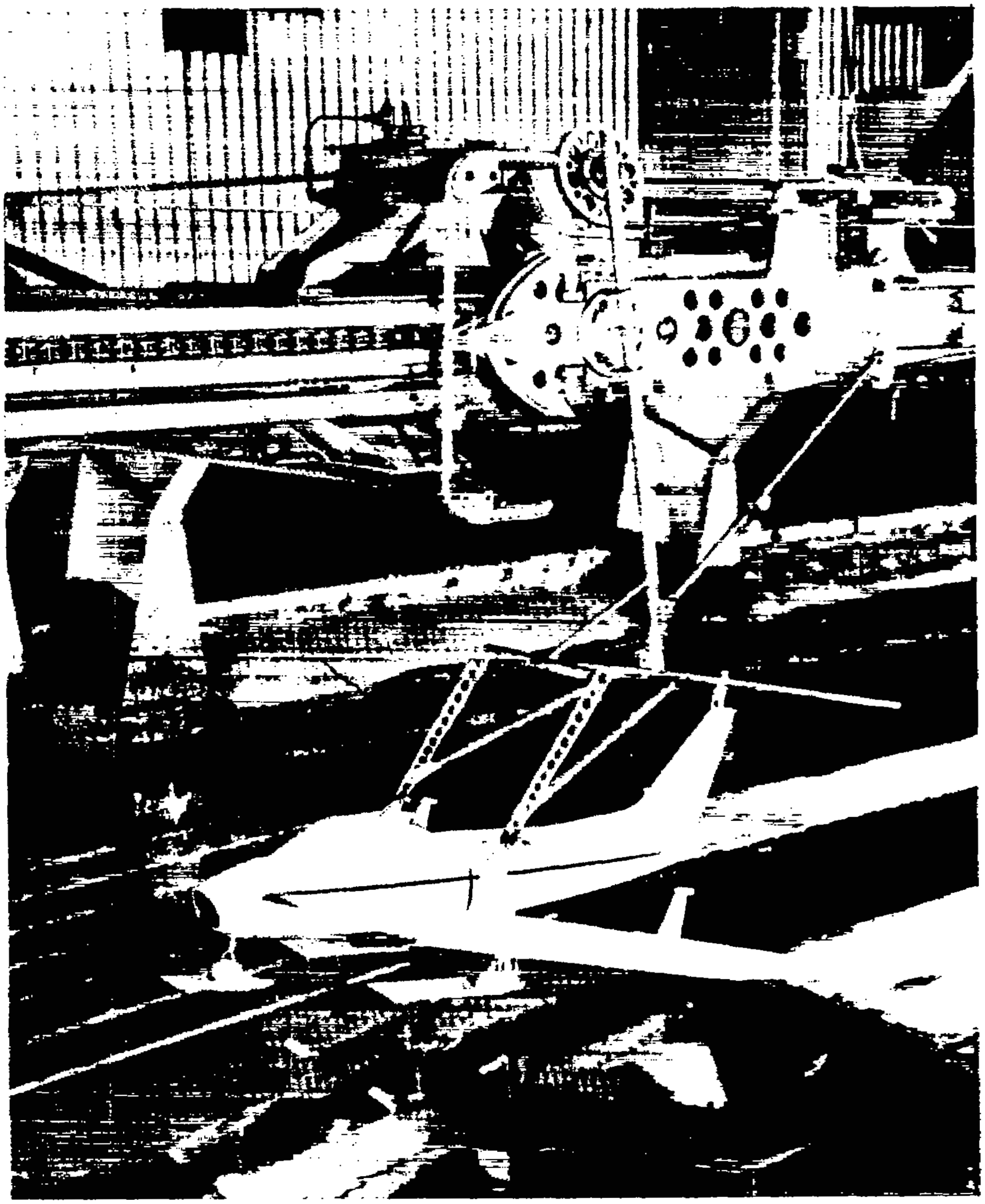

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Figure 6.- The model equipped with tri hydro-skis set up for launching from the monorail in Langley tank no. 2.

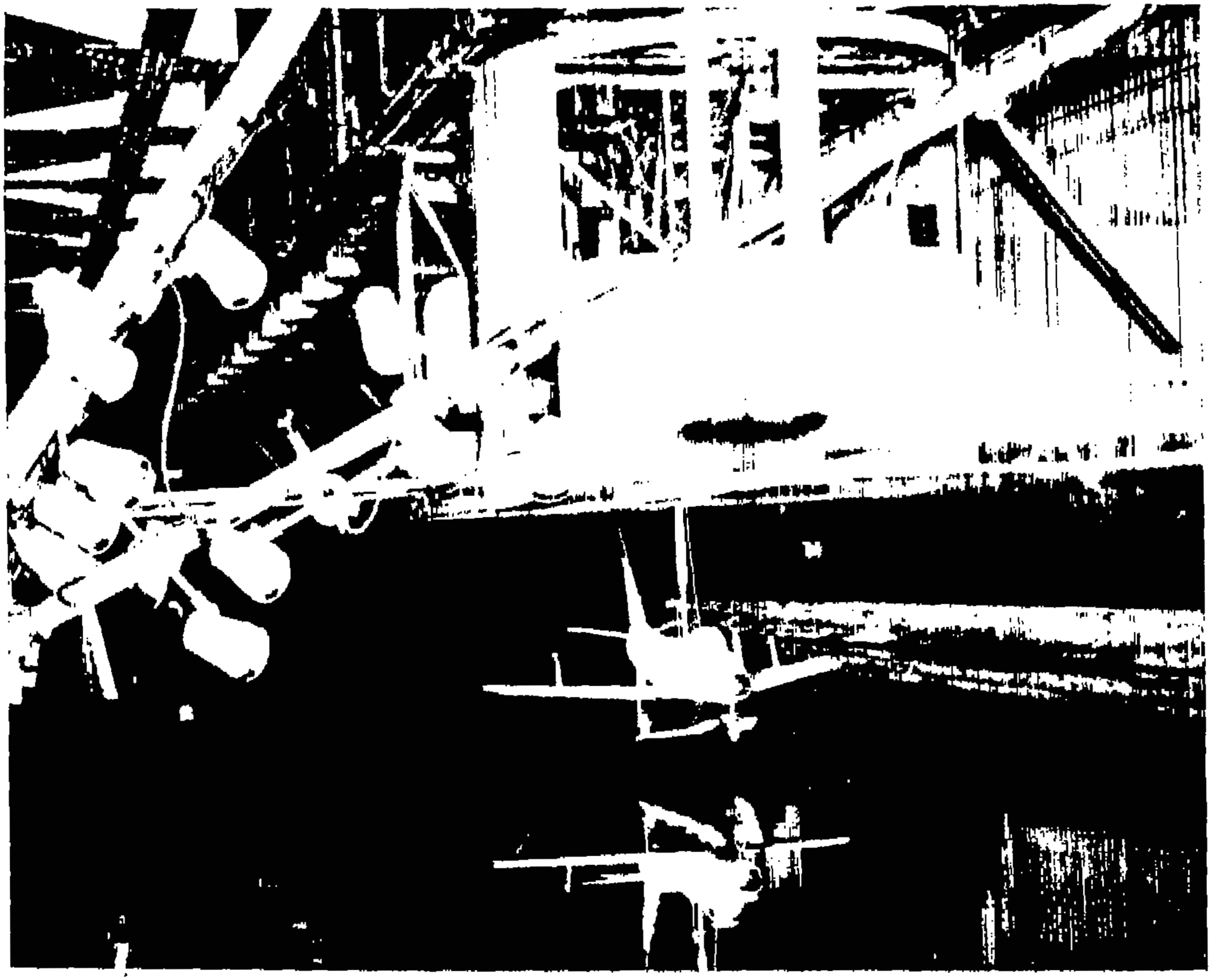

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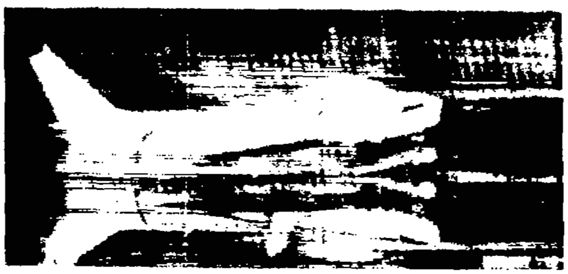
Figure 7.- Model setup for take-off tests on the main carriage in Langley tank no. 2.

speed approximately 50 knots

skis penetrate water



model trims up

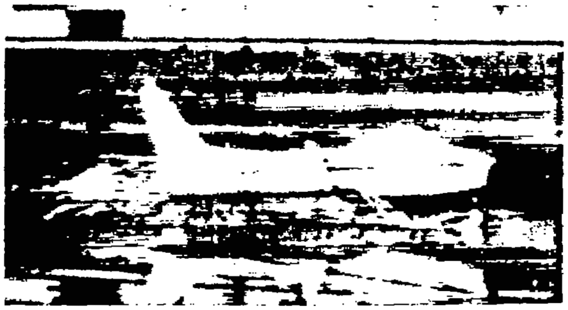
makes small bounce

settles back on skis

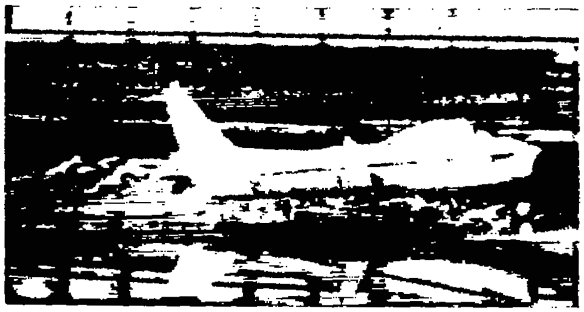
(a) Entering water. L-58-102

Figure 8.- Sequence photographs of typical transitions from a ramp with 6-to-1 slope with the twin-hydro-ski configuration. All values are full scale.

speed approximately 32 knots
near transition



main gear contacts ramp



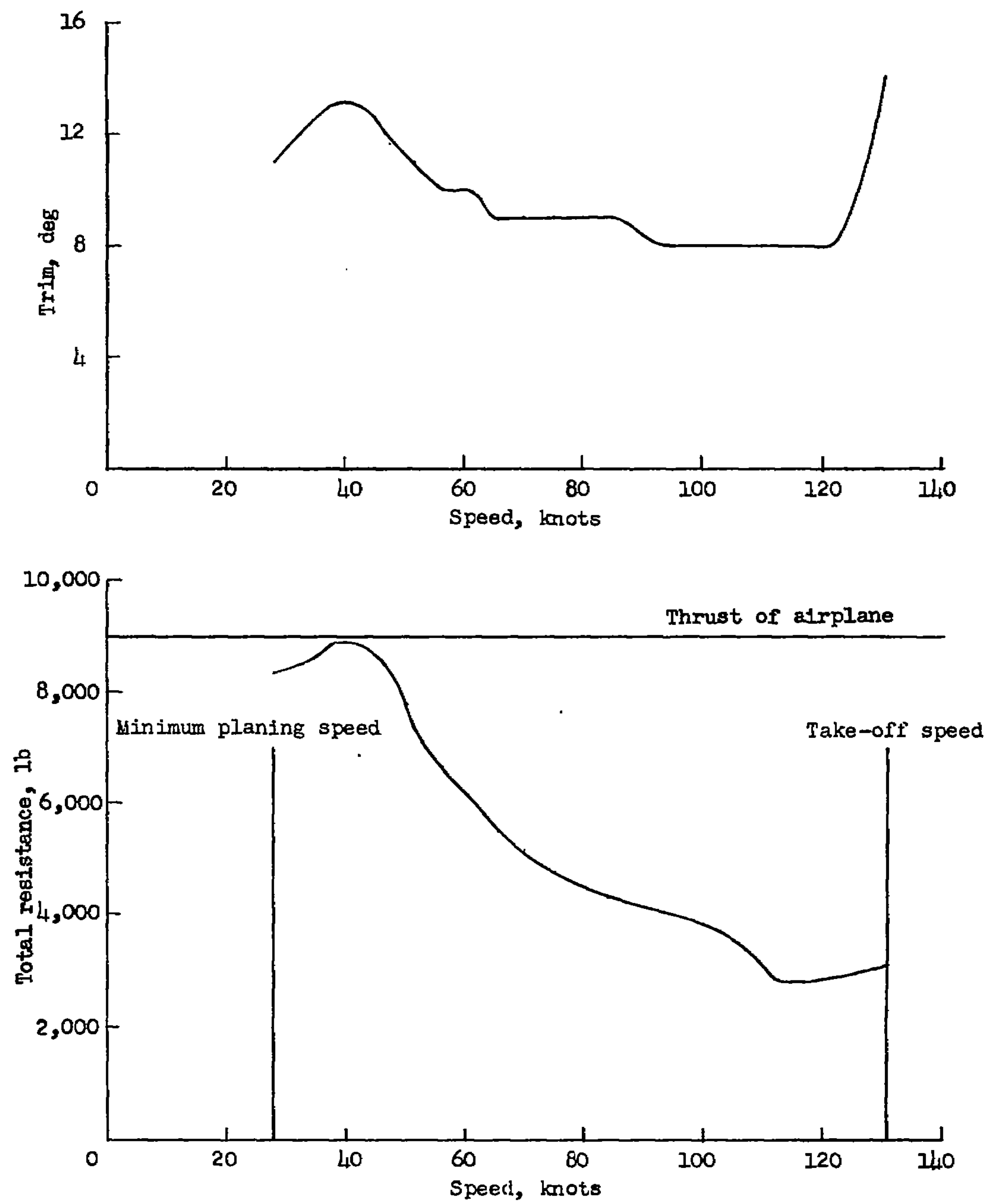
nose gear contacts ramp

model makes small bounce

taxis up ramp

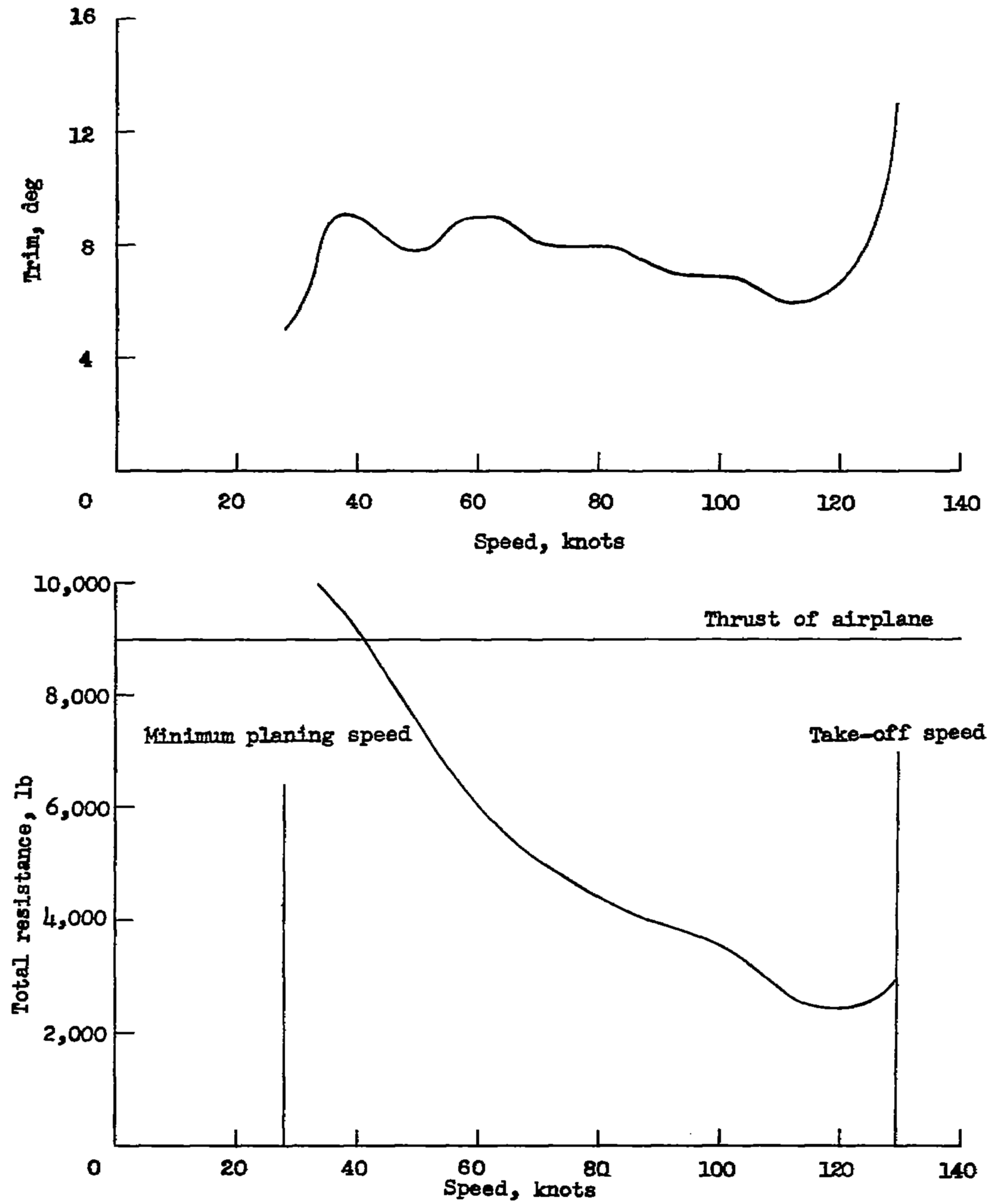
(b) Leaving water. L-58-103

Figure 8.- Concluded.



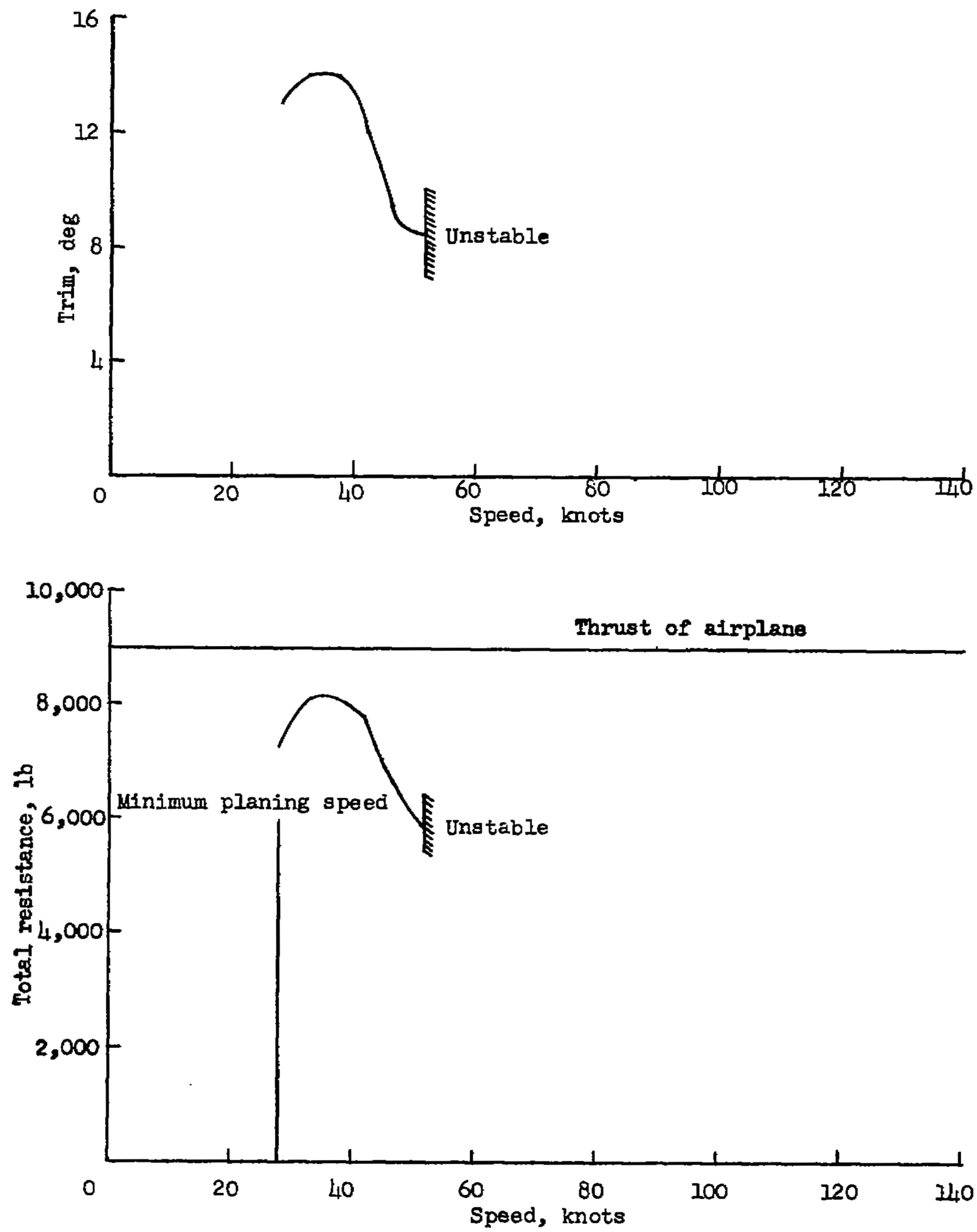
(a) Twin-ski configuration; flap deflection, 20°.

Figure 9.- Take-off resistance and trim for the model with hydro-skis installed. All values are full scale.



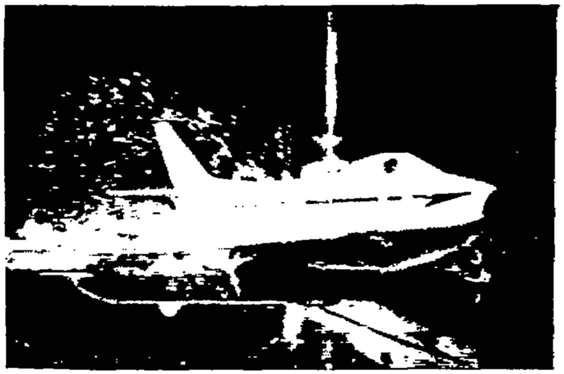
(b) Twin-ski configuration; flap deflection, 38°.

Figure 9.- Continued.

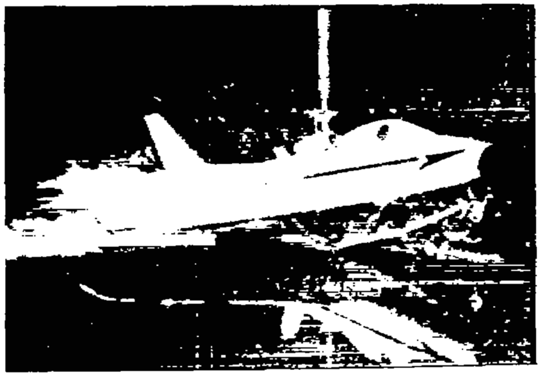


(c) Tri-ski configuration; flap deflection, 20°.

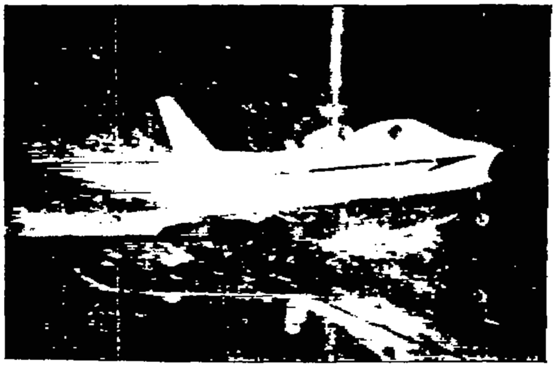
Figure 9.- Concluded.



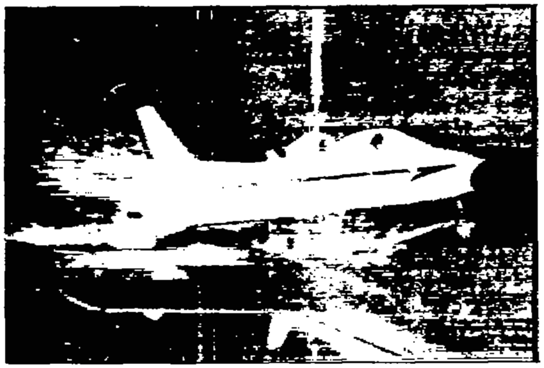
28 knots



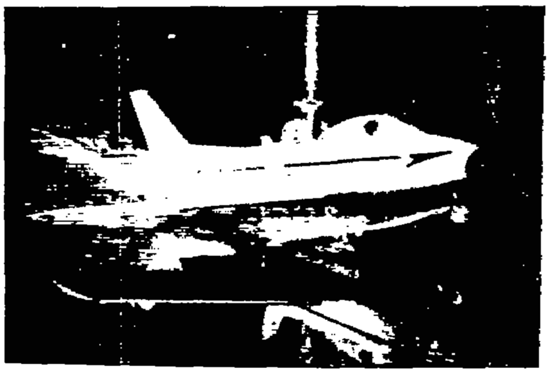
42 knots



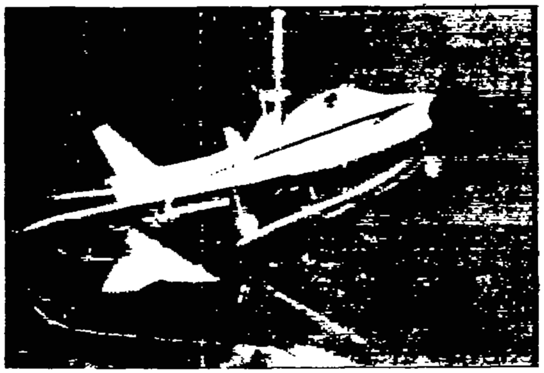
56 knots



70 knots



94 knots



132 knots

L-58-104

Figure 10.- Sequence photographs of a take-off run with the twin hydro-ski configuration, flaps deflected 20°. Speeds are full scale.